ABS Data Compressing Kickoff Meeting - Status, Future Work, and Roadmap

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ABSTARCT

ABS will produce unprecedented volume of information rich atmospheric and environmental remote sensing data. In this part 1 presentation we are reviewing the current progress/approach of data compression and noise estimate. The future work to achieve both ground-based and on-board ABS data compression needs are also conversed. A roadmap designed to cover the end-to-end study needs is outlined as well.

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Outlines

- Hyperspectral Data Information/Background
  - Data Volume; spectral, temporal, and gradient Inf. Con.
- GIFTS/NAST-I/AIRS data Compression Study Status
  - Will be discussed in details this afternoon
- Proposed Data Compression Approaches
  - Ground Based & On-board
  - Noise Estimation
- Roadmap for ABS Data compressing
  - Measurement Simulation, Data Compression Study, Defined Requirements, and Recommend Solution

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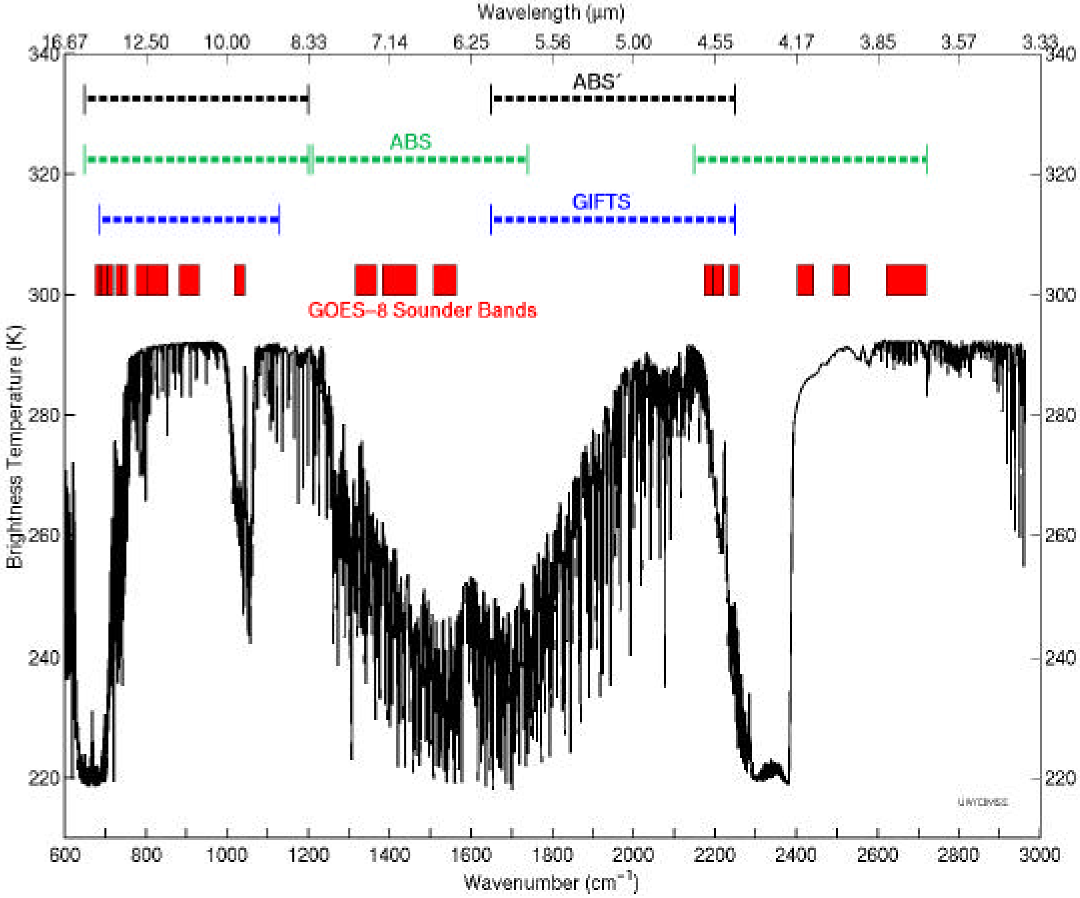
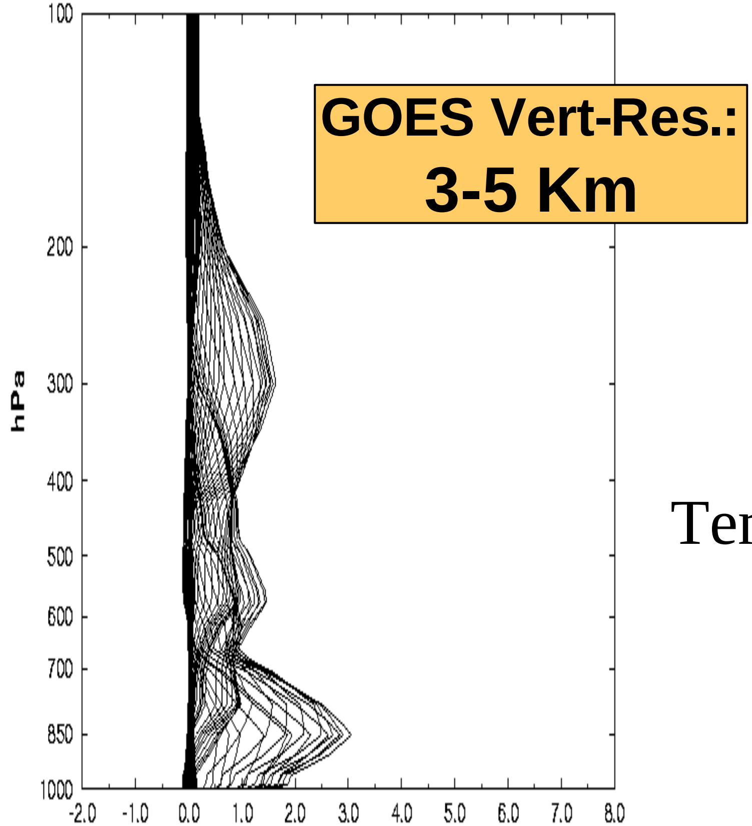
ABS Hyperspectral IR Data -

What to Expect -> Lots more data than we can handle

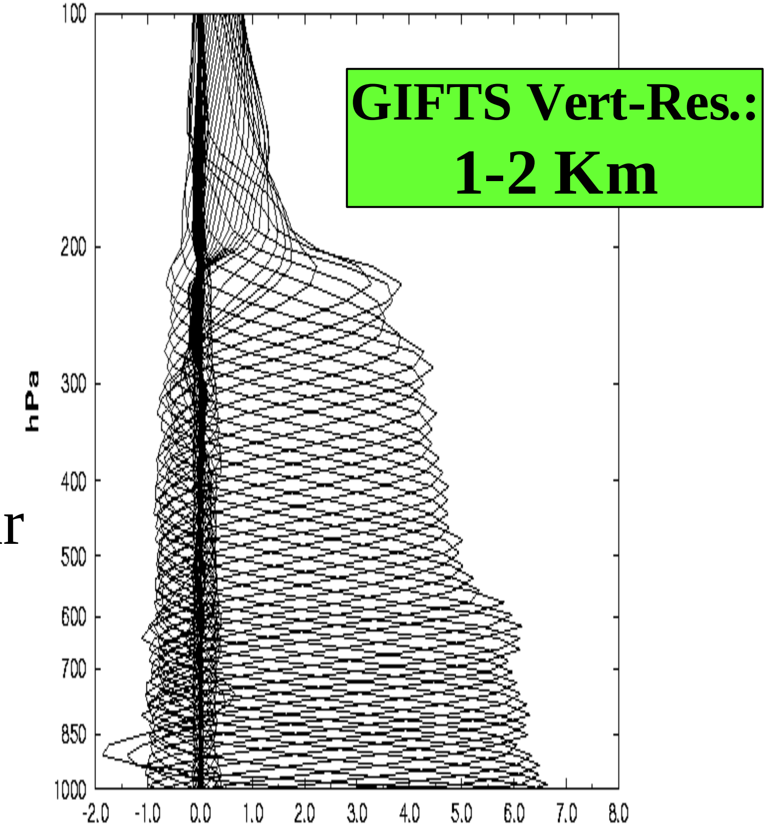
ABS/GIFTS ~ 3000 ch. per IFOV



Hyperspectral Data Information -
Spectral Information -> Vertical Resolution



Temperatur



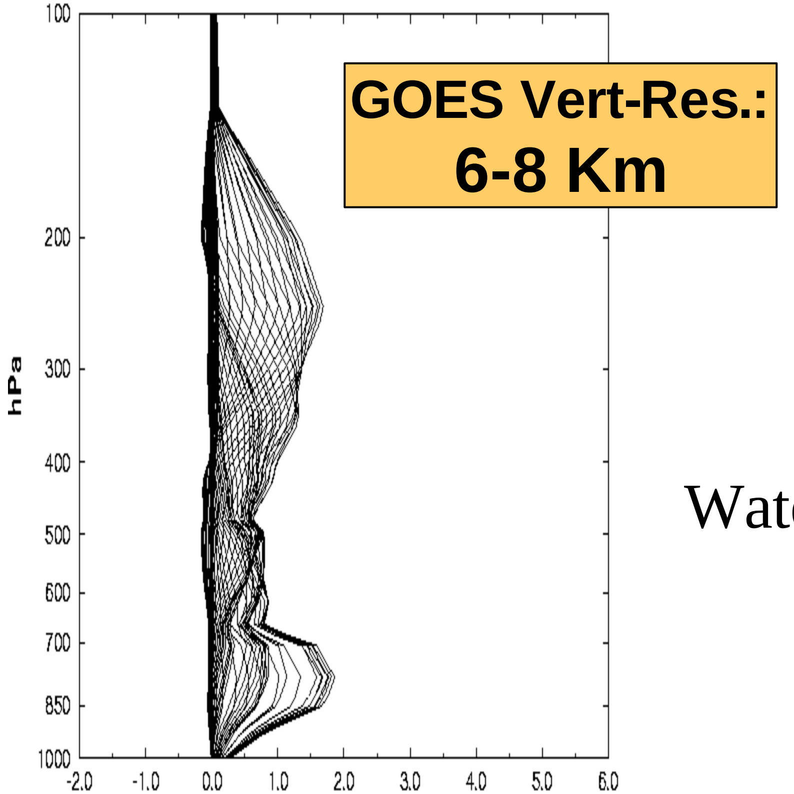
Current - GOES

~3 Pieces

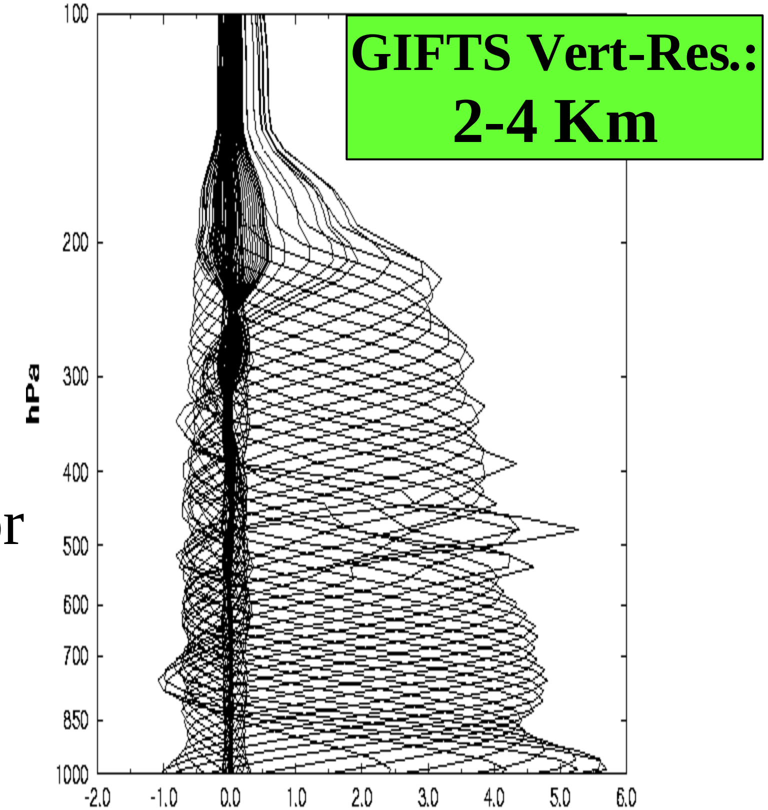
GIFTS

10-12 Pieces

Hyperspectral Data Information -
Spectral Information -> Vertical Resolution



Water Vapor



Current - GOES

~2 Pieces

GIFTS

8-9 Pieces

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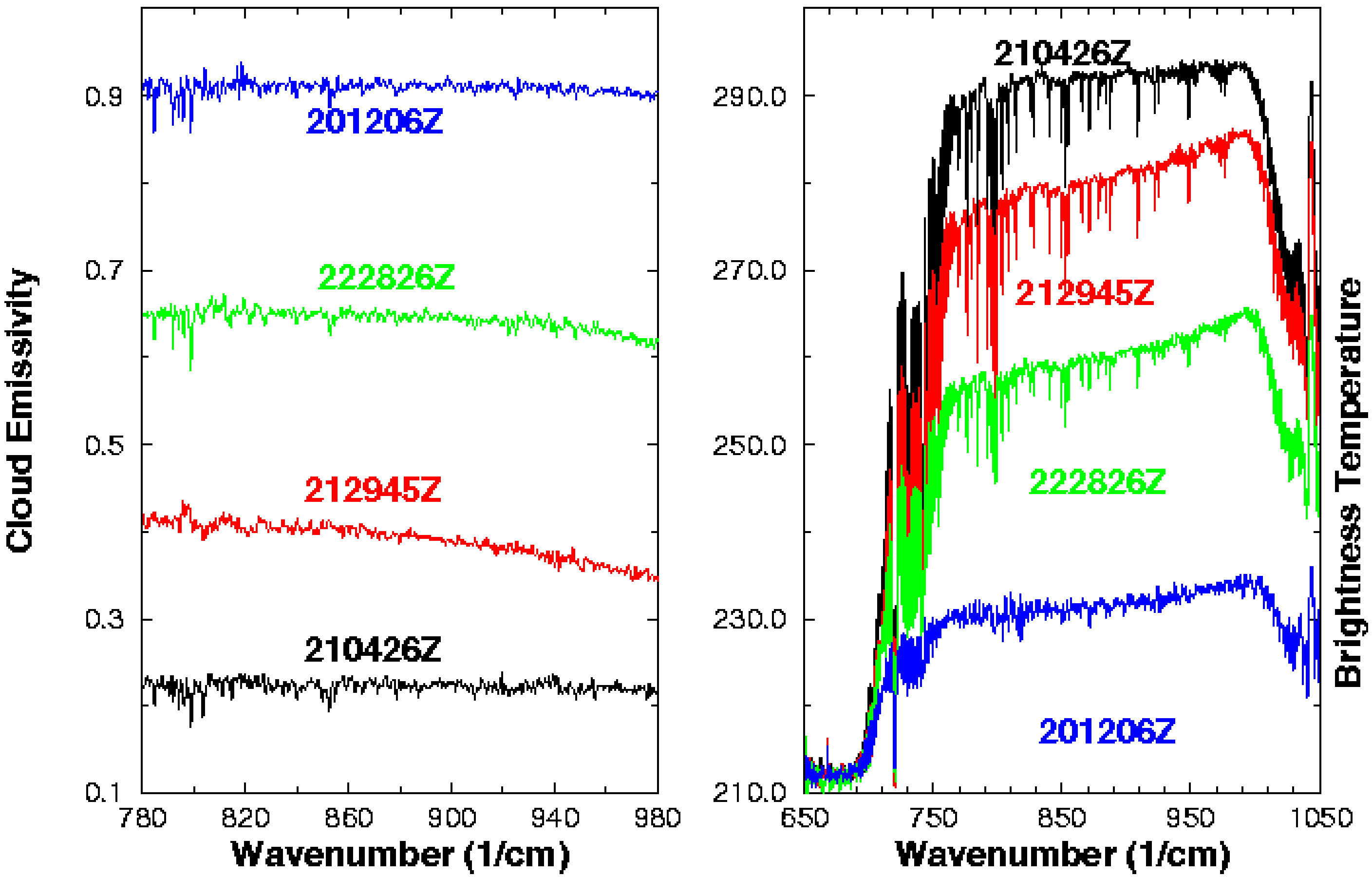
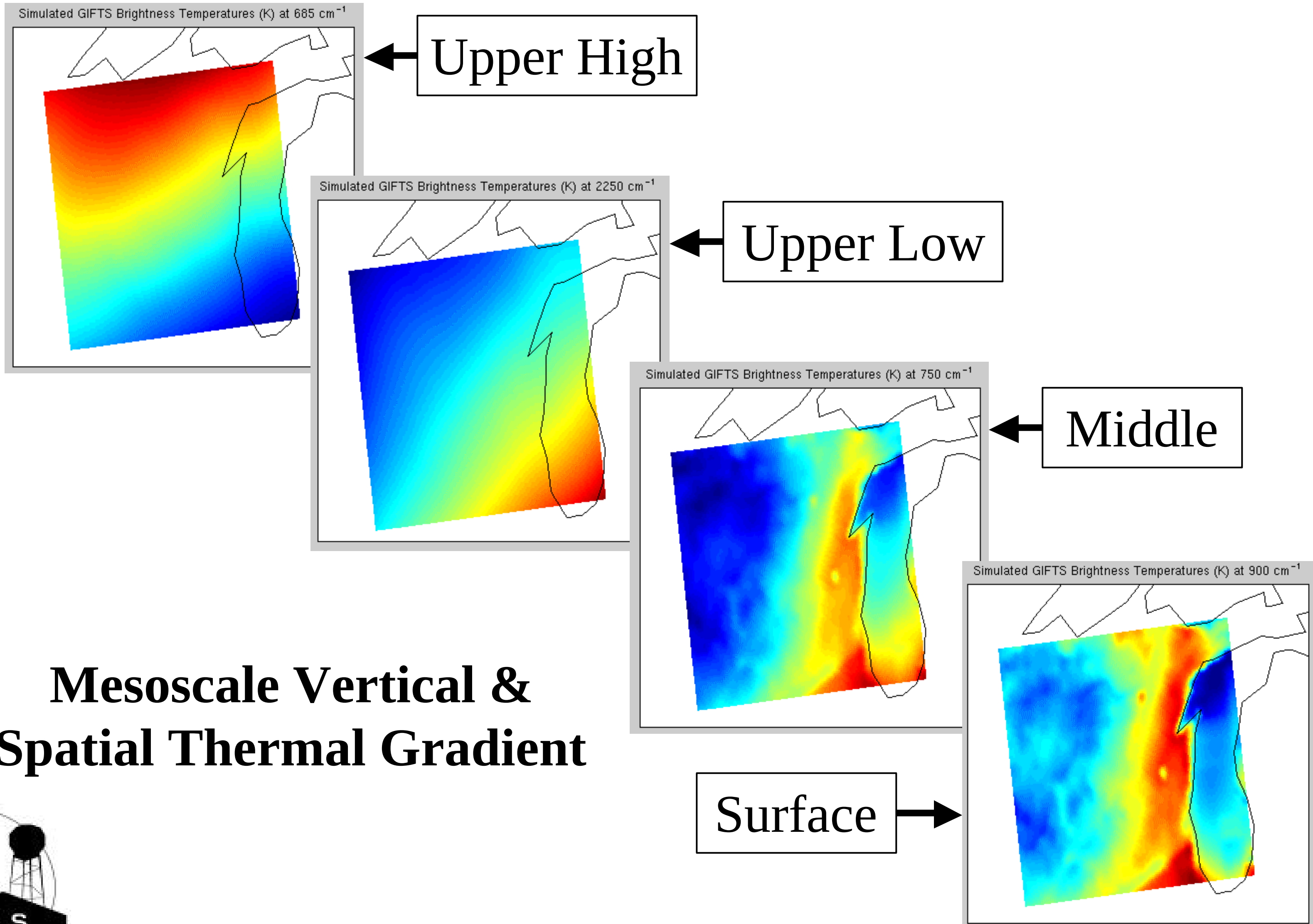
Hyperspectral Data Information - Spectral Information -> Marco & Micro Cloud Property



Hyperspectral Data Information -

Spatial Information -> Gradient



Mesoscale Vertical &
Spatial Thermal Gradient

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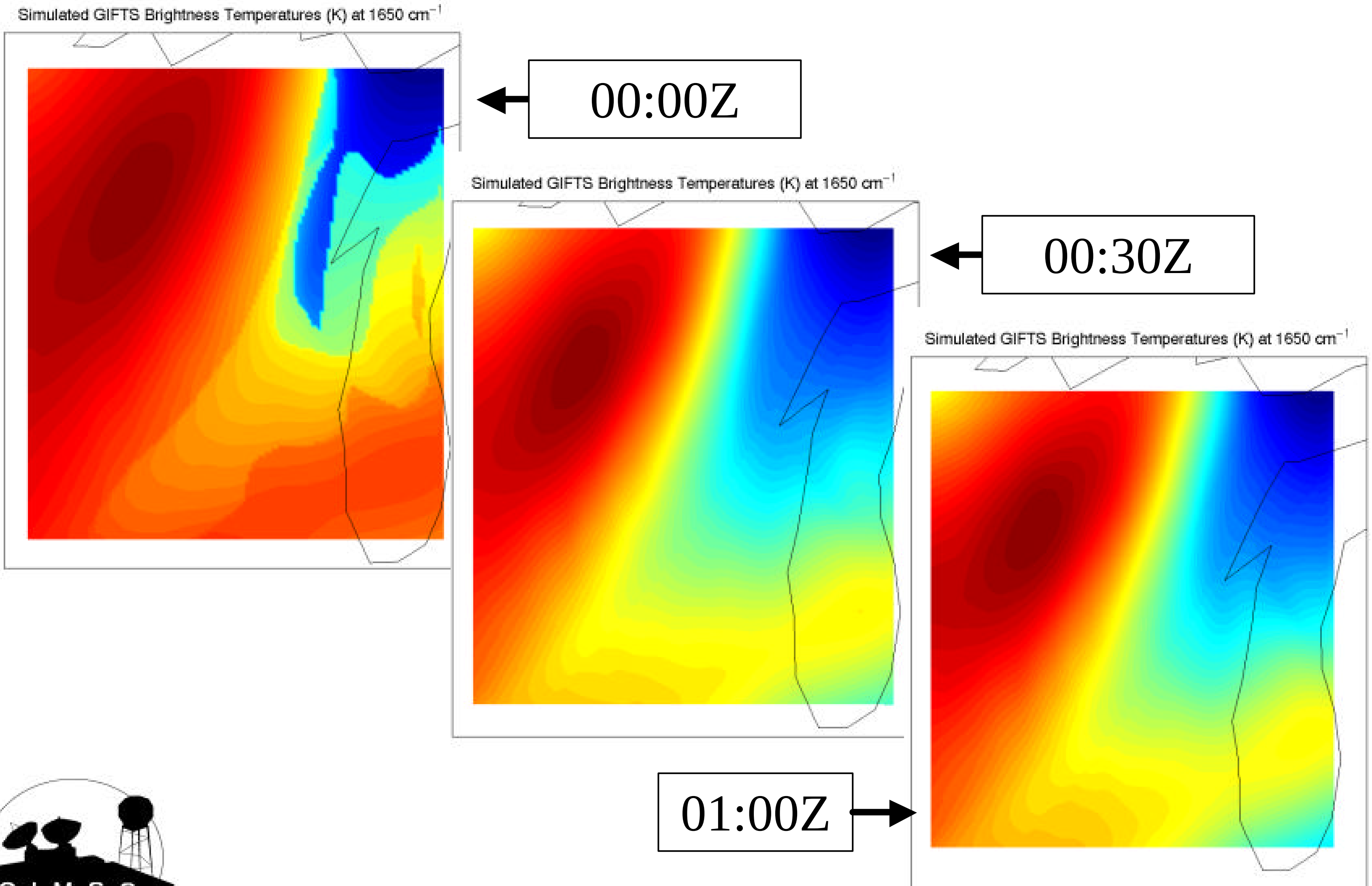
Hyperspectral Data Information -
Temporal Information -> Moisture Transport



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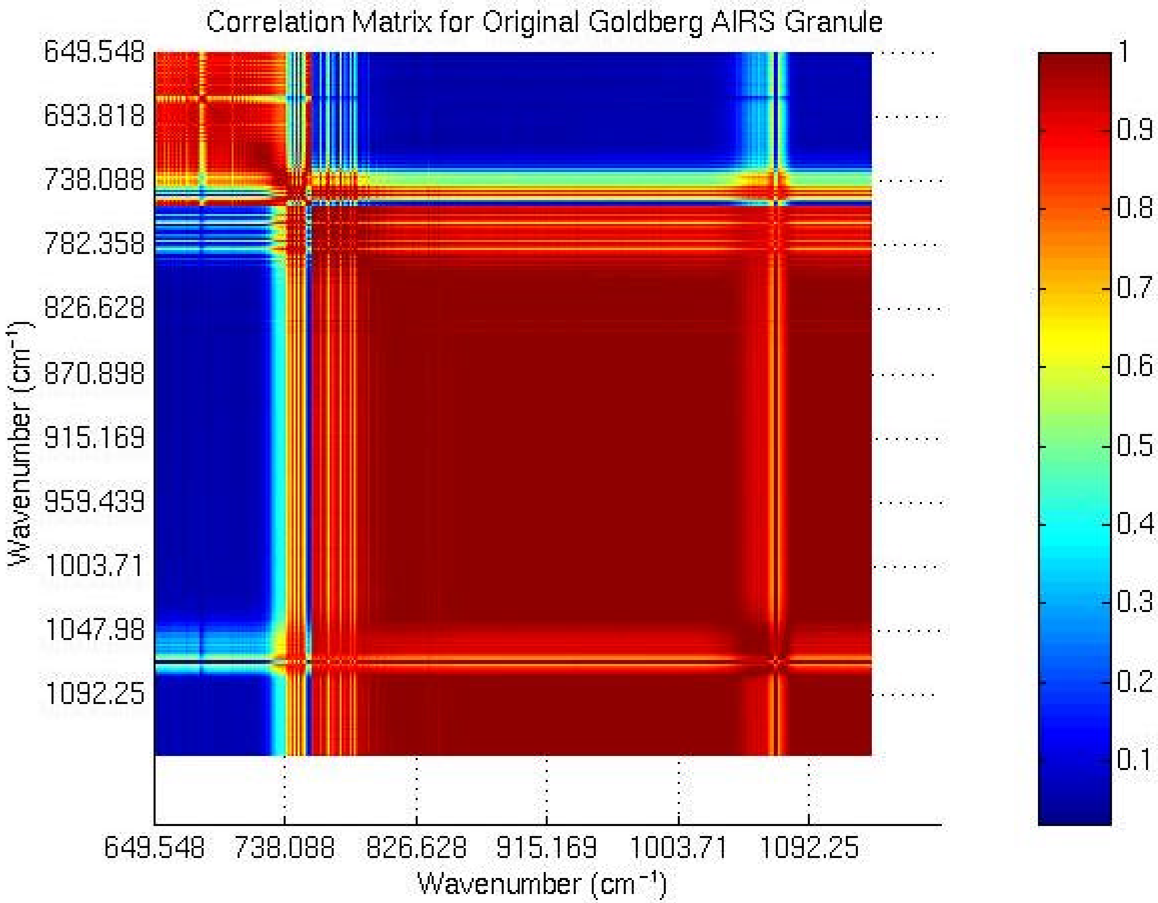
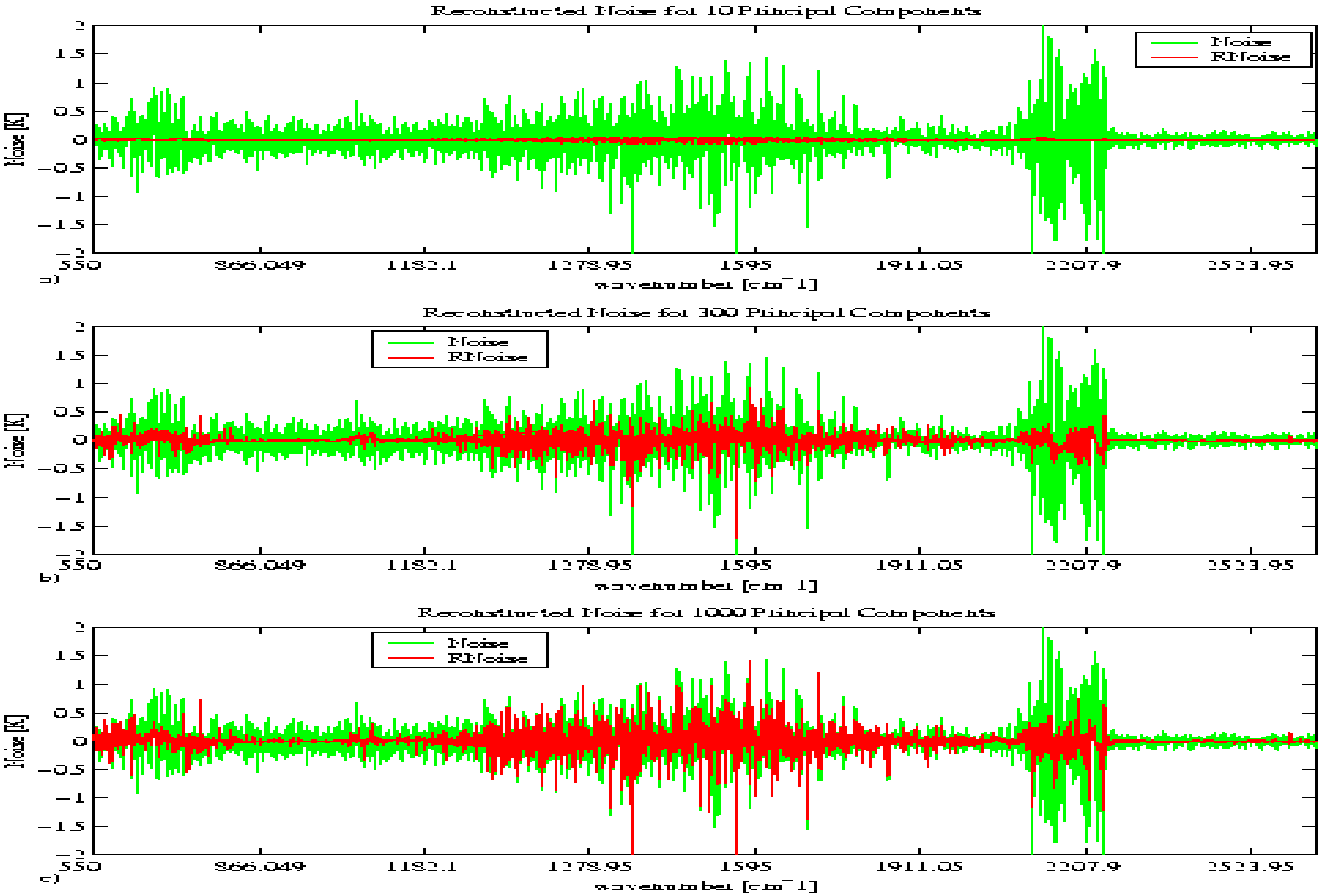
Hyperspectral Data Information - Spectral Correlation -> Data Redundancy?



What is PCA?

- PCA is Principal Component Analysis, a classical approach to the problem of linear (independent) feature extraction
- PCA essentially performs Singular Value Decomposition of the Covariance Matrix
- For Gaussianly distributed input, PCA extracts statistically independent features

Why Principal Component Compression (PCC) - Reason I : Noise Reduction



Noise (K)

10 PC

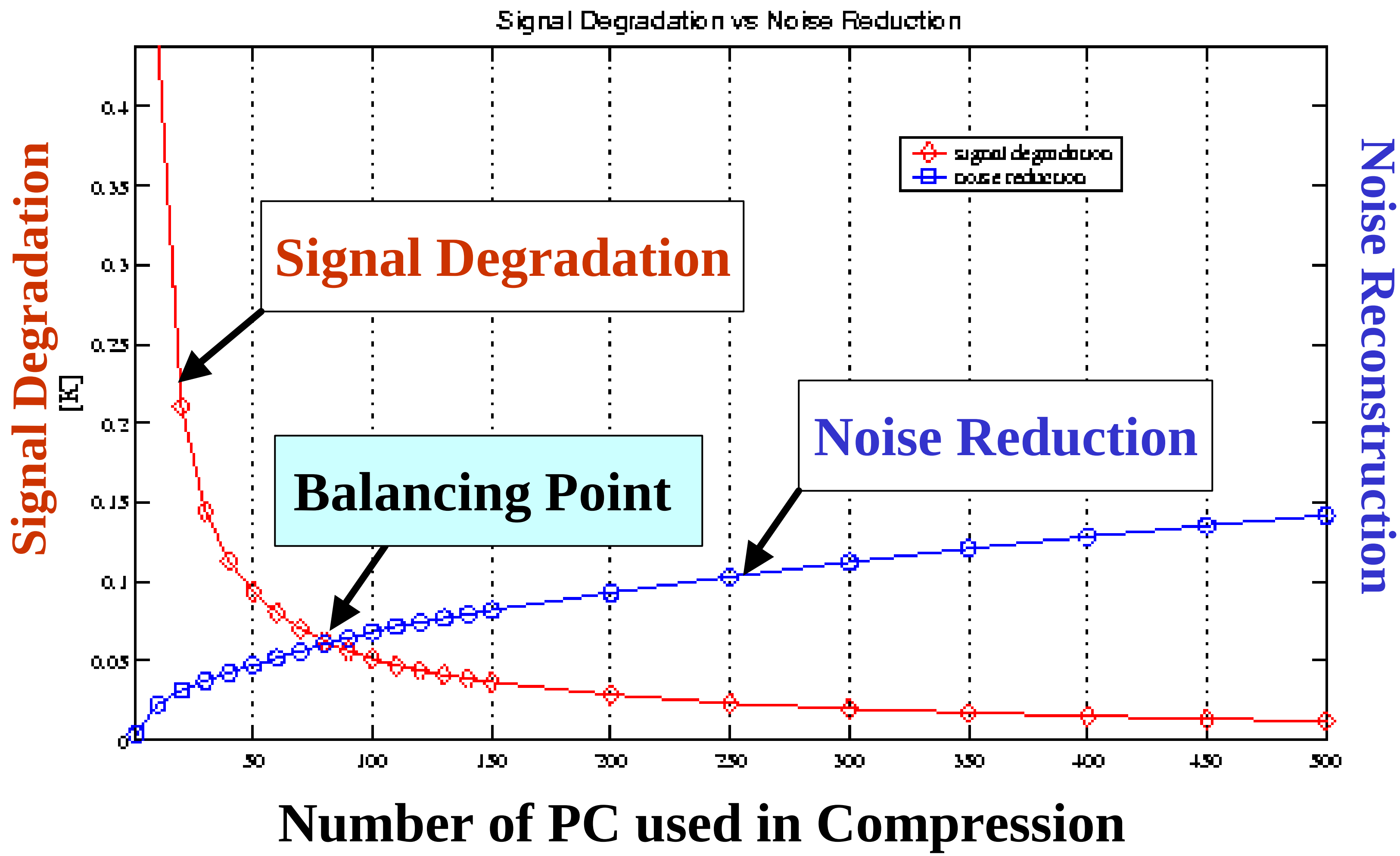
100 PC

1000 PC

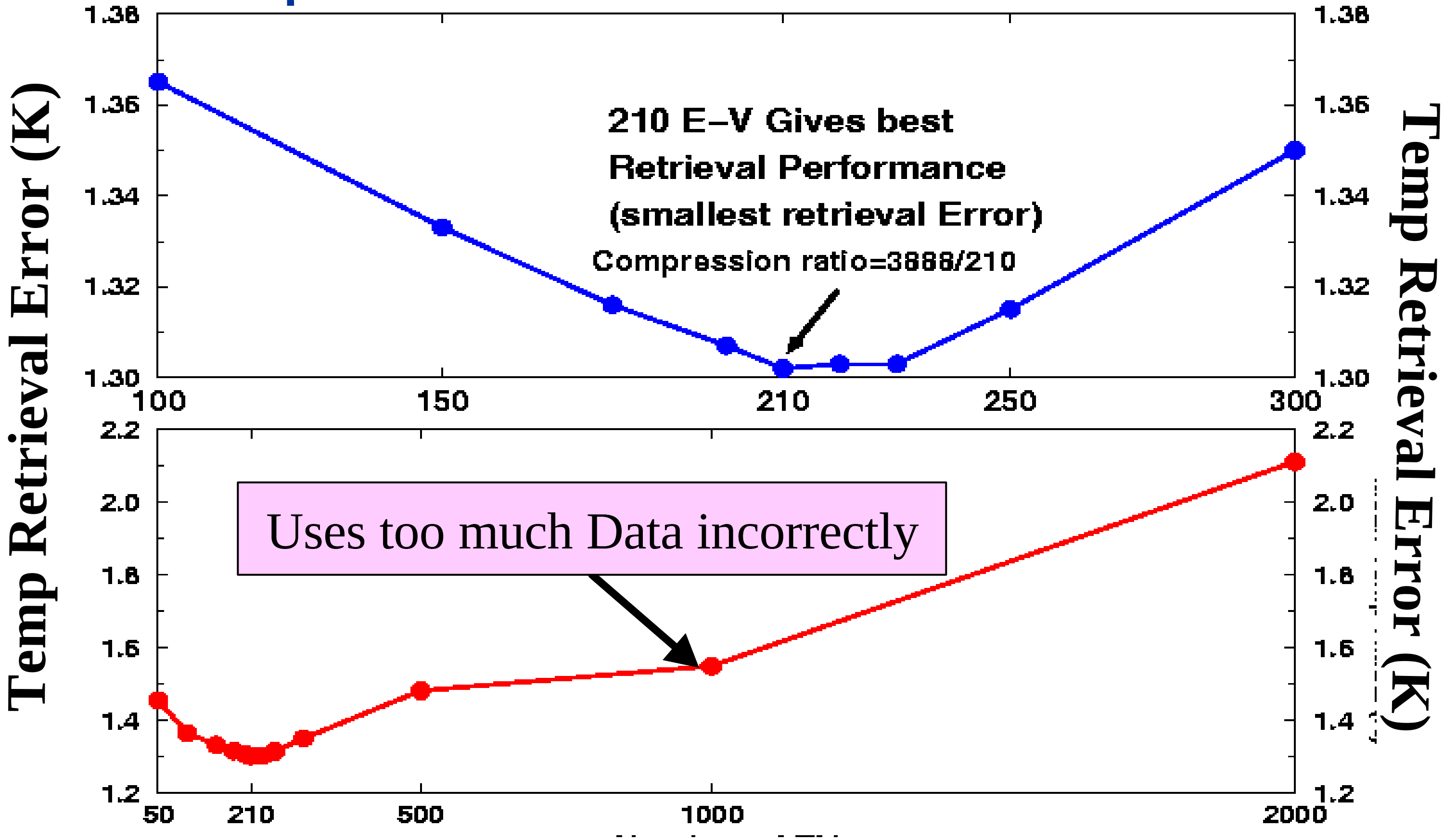
Wavenumber (1/cm)

Green-Single Noise Spectrum **Red-PCC Noise Spectrum**

Why PCC - Reason II : Tunable Signal Loss



Why PCC - Reason III : Discriminate Independent from Redundant Data



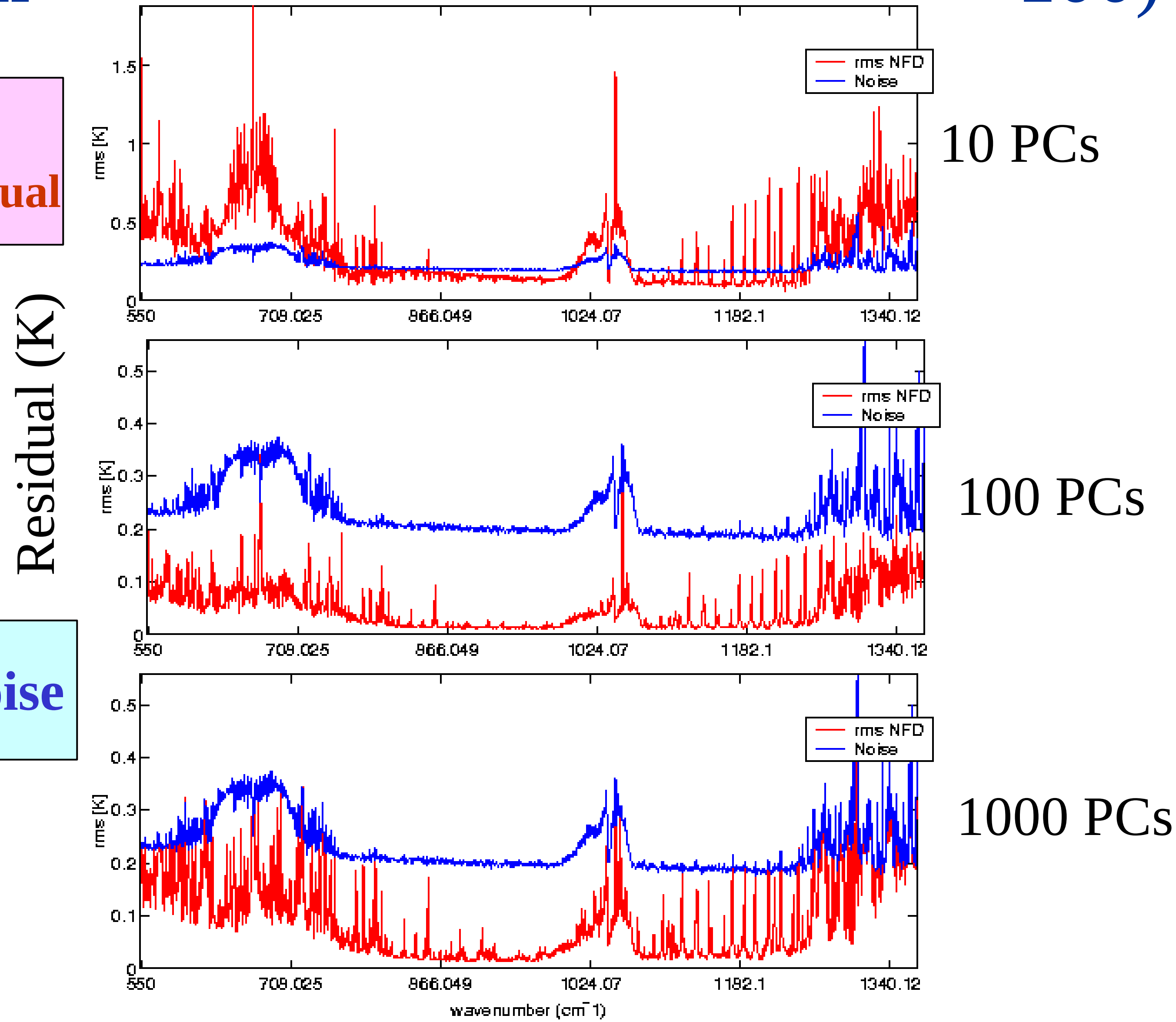
# of PC used

Uses of independent information only will improve retrieval performance

Why PCC - Reason IV : Consolidate Measurement Information (~2000 to ~100)

Blue - Noise
Red - PCC Residual

Residual < Noise



Principal Component Compression (PCC)

Pros & Cons

Cons:

1. **Requires PCA (Significant Computational Costs)**
2. **Requires Measurement Reconstruction**
3. **Representative Set Selection for PCs is an issue**

Pros:

1. **Noise Reduction/Estimation**
2. **Tunable Signal Loss**
3. **Discriminate Independent from Redundant Data**
4. **Increase Information Density**
5. **Intermediate Retrieval Processing step**
6. **Suitability to Available Computing Systems**

Hyperspectral Data Processing -

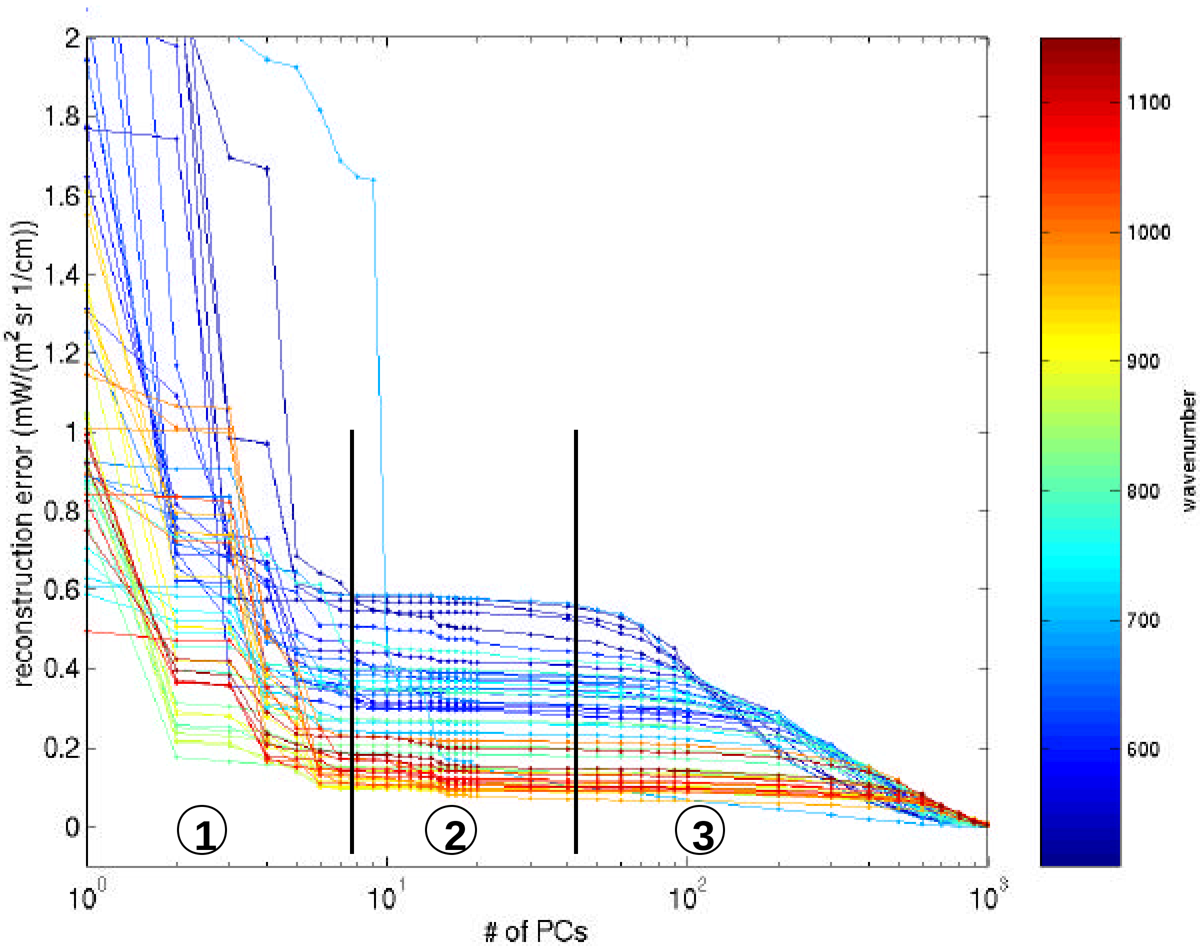
Why can we Estimate Noise Effectively ->

Signal & Noise are Estimated Separately

1 - Signal under represented

2 - Signal well represented; Noise filtered

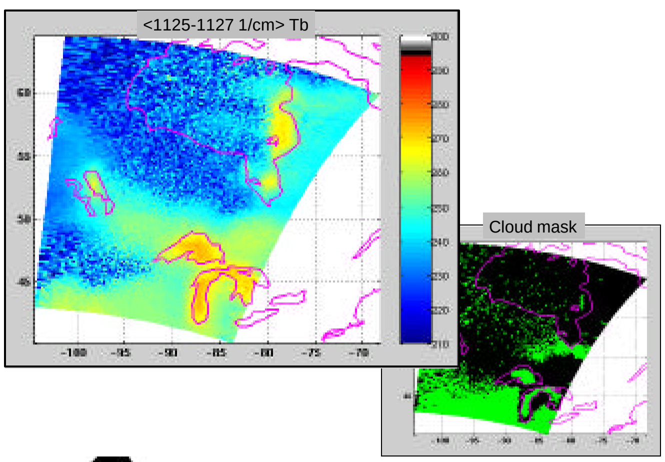
3 - Signal & noise both duplicated



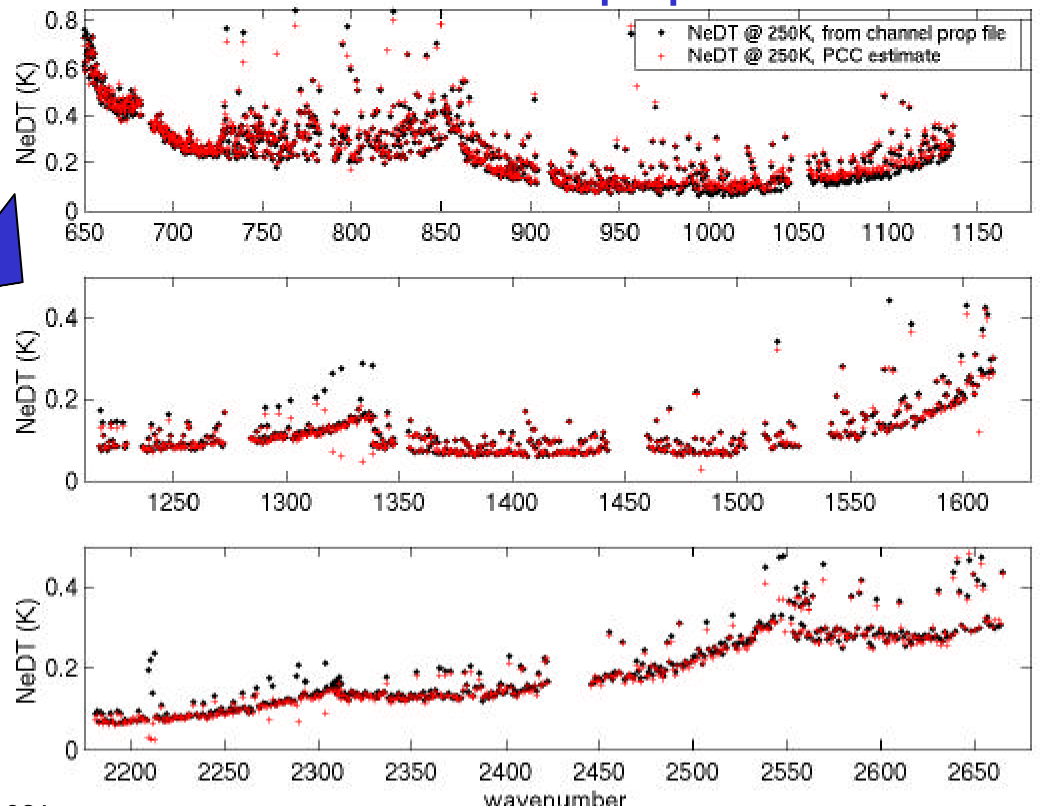
Hyperspectral Data Processing -
Why can we Estimate Noise Effectively ->
Noise are Well Estimated

Noise estimated well represent actual measurement noise

15-Dec-2000 granule 081



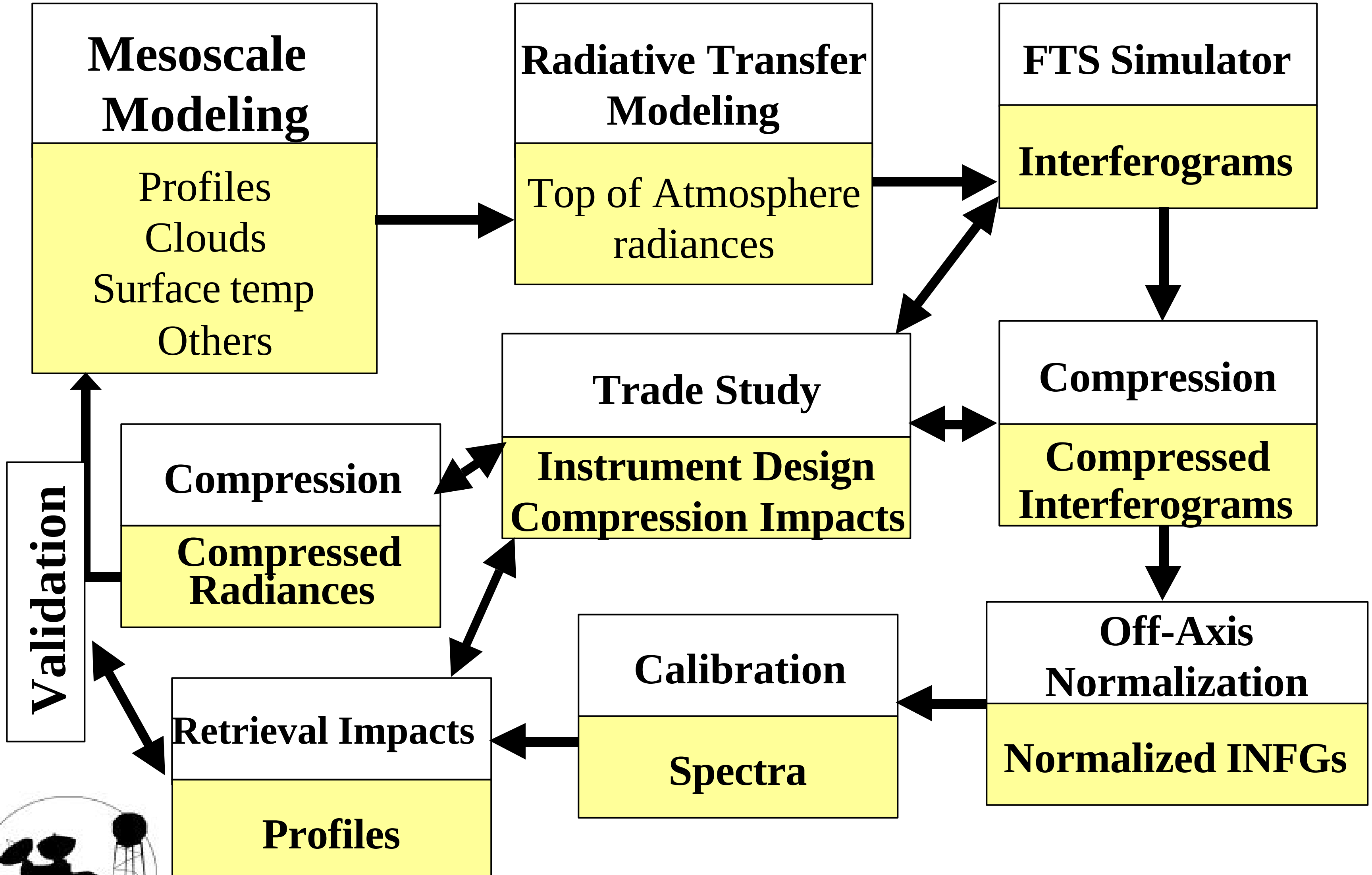
NeDT@250K: estimated from granule 081 and values from channel properties file



081

badFlag=0, radQual

ABS Measurement Simulation and Data Compression - Top Level Flow Diagram



ABS FTS Simulation

Input Calculated Top of Atmosphere Spectra

↓

- Add Instrument Background
- Apply Instrument Responsivity
- Apply Numerical Filter
- Apply Instrument Line Shape Function
- Apply Off-axis Interferogram Sampling

↓

Output ABS Interferograms or Spectra

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ABS Measurement Noise Simulation

Input ABS ???

↓

- Apply ??
- Apply ??
- Apply ??
- Apply ??
- Apply ??

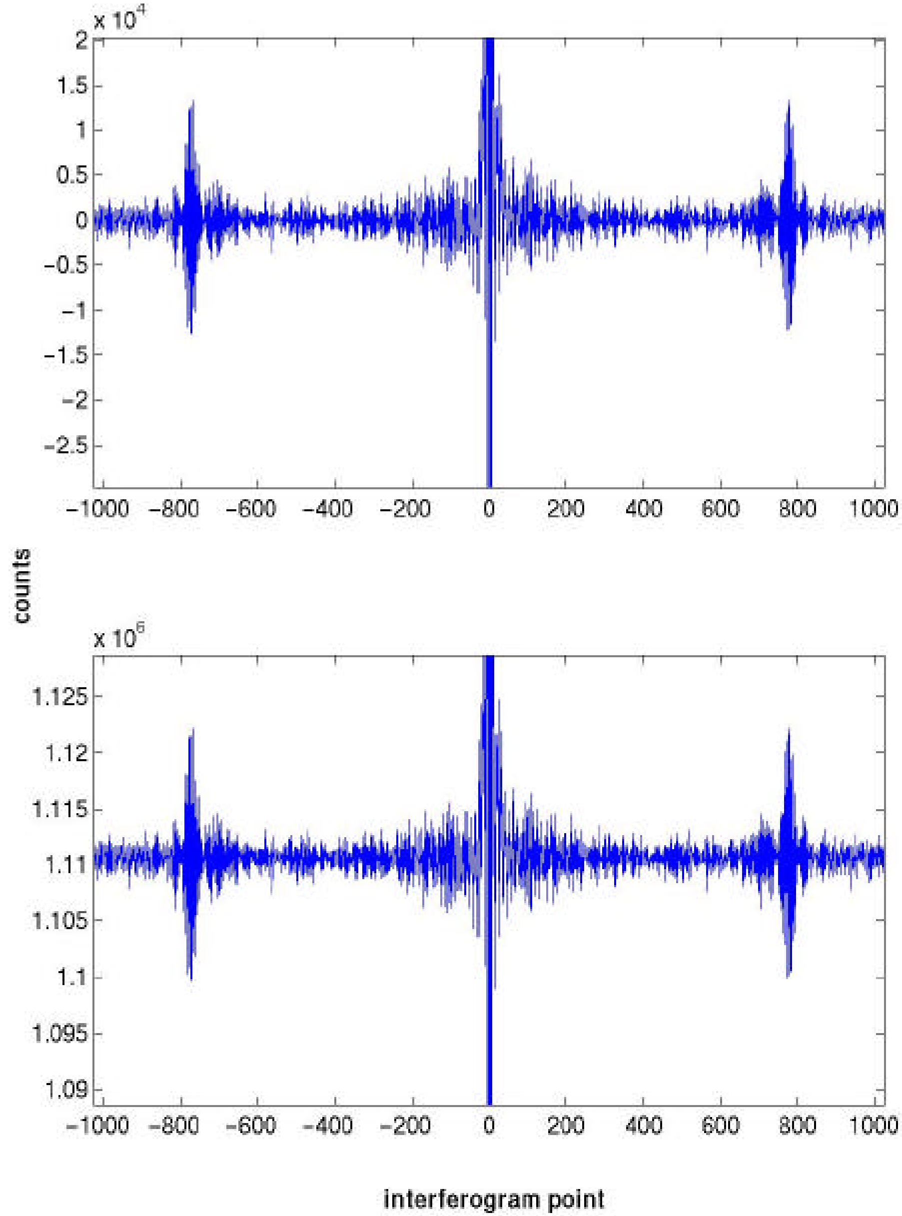
↓

Output ABS Noise Spectra

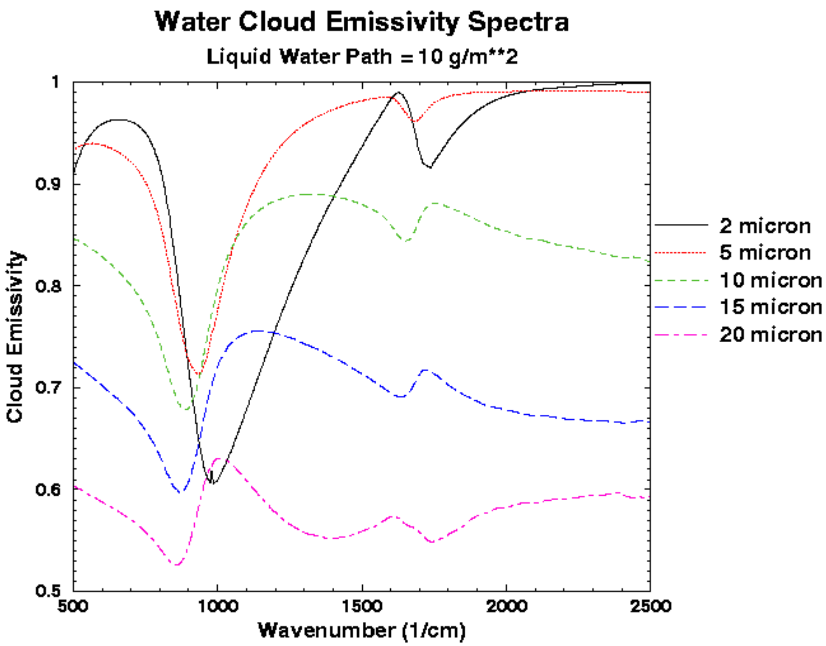
Example LW Interferogram with variable Gain and Offset

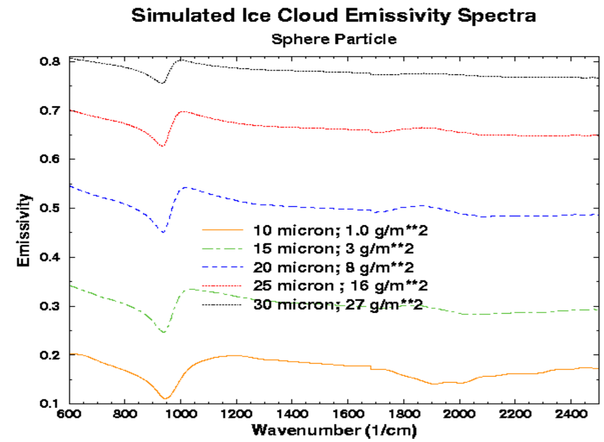
without effects

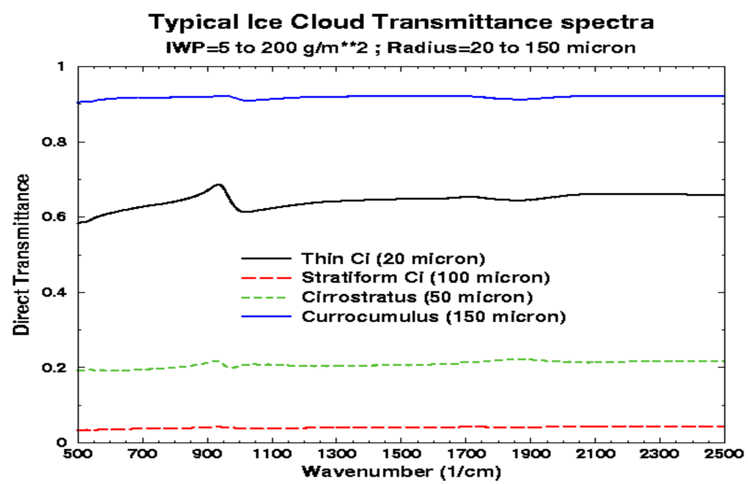
with effects



Parameterization of Ice and Liquid Cloud







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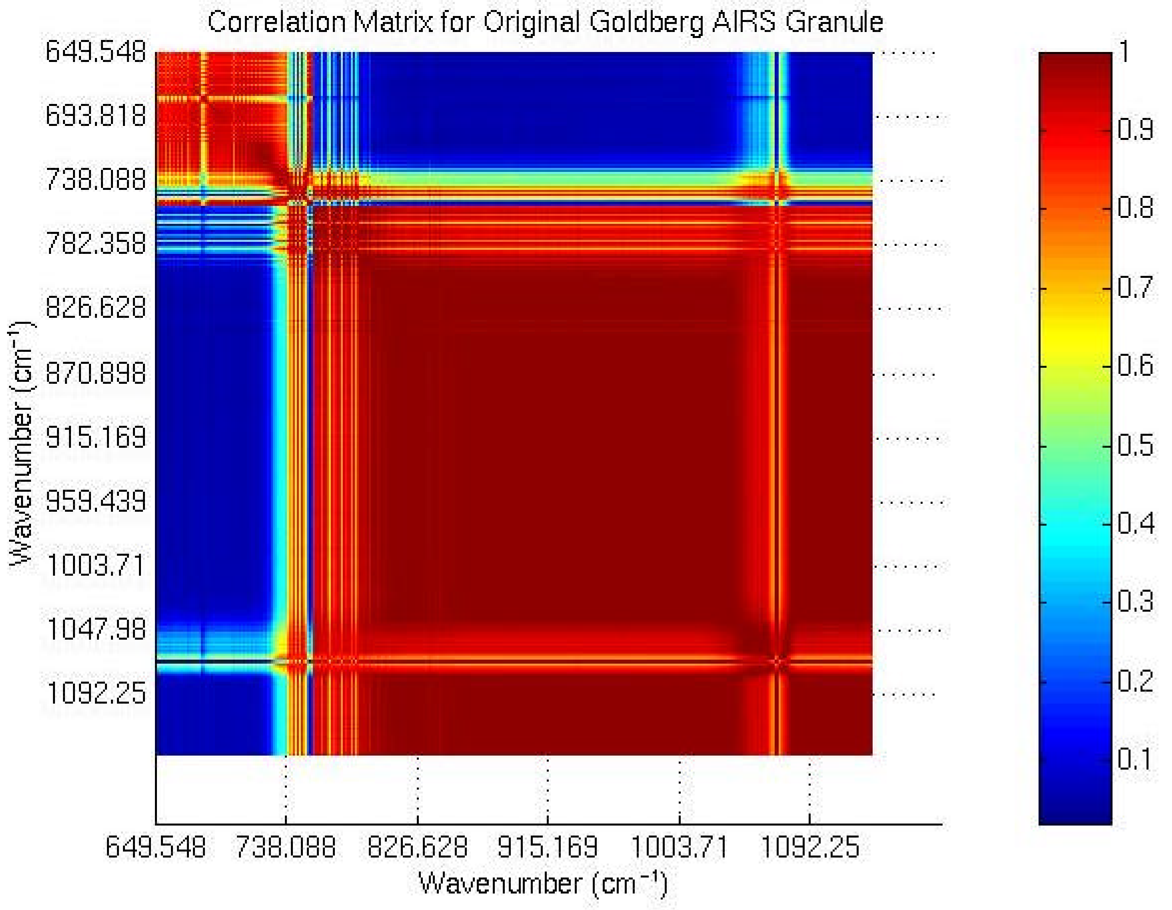
Raw Data Spectral Correlation



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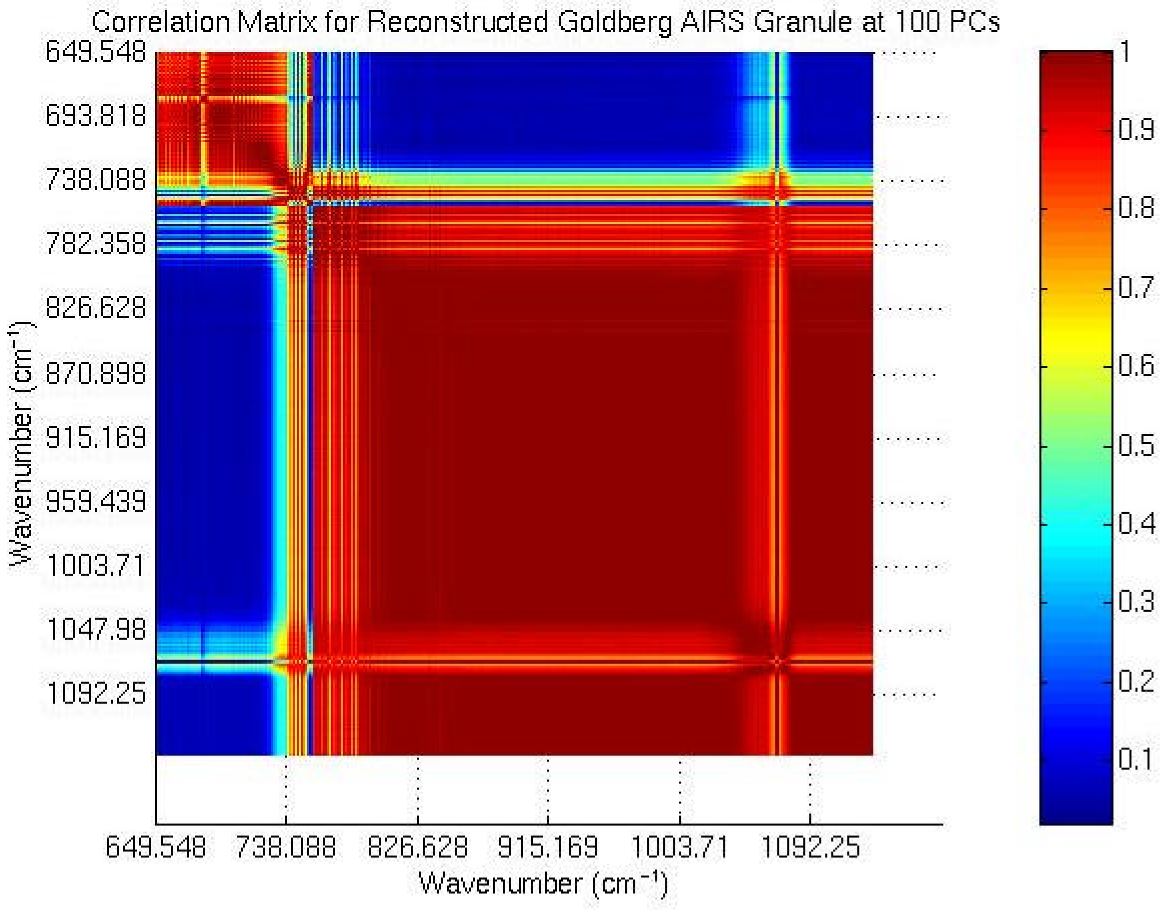
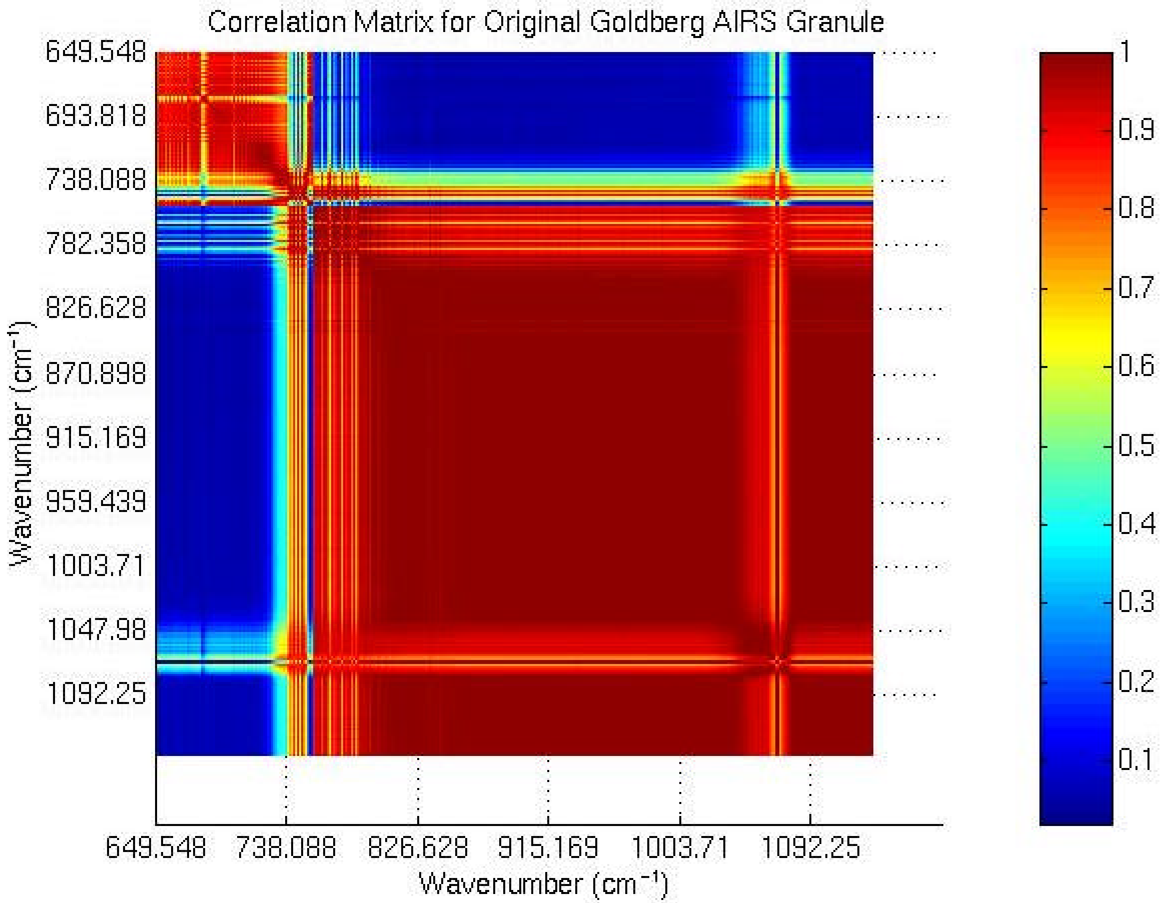
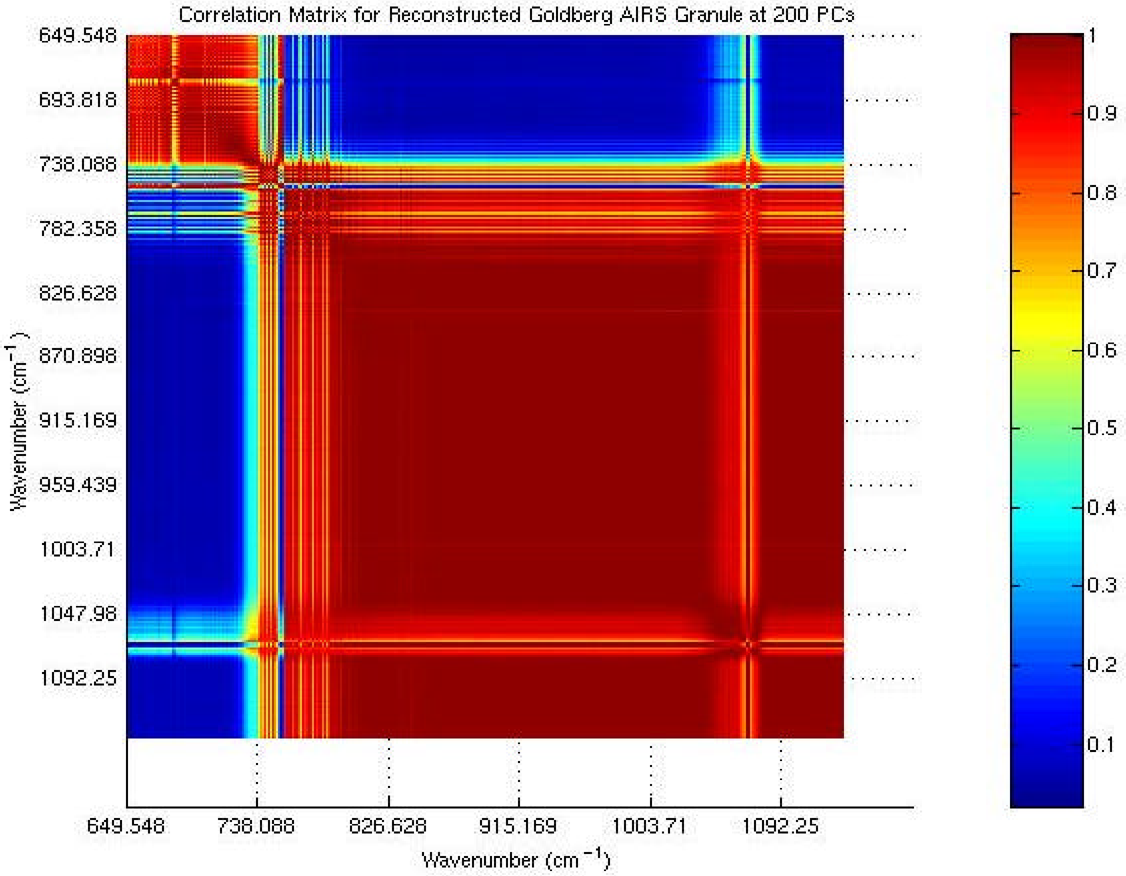
100 PC Compressed Data Spectral Correlation



Raw Data Spectral Correlation

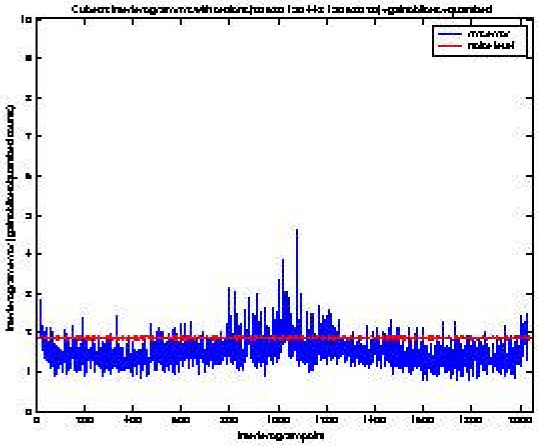


200 PC Compressed Data Spectral Correlation

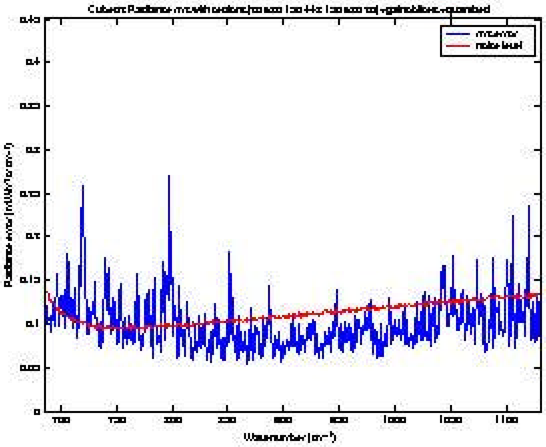


Compression Residuals - Raw or Calibrated Domains

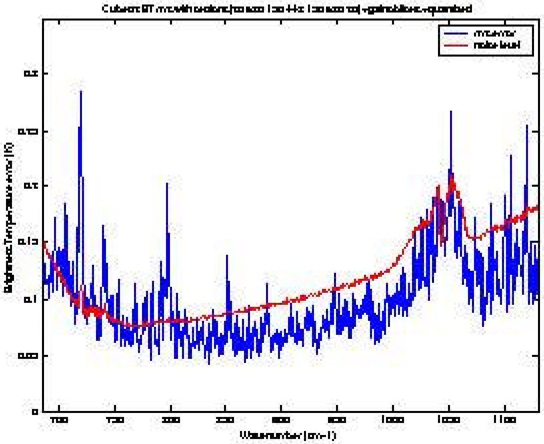
Interferogram



Radiance



Brightness Temp.



Definitions

Old DPC: Old Dependent Principal Component (fixed point segments)

New DPC: New Dependent Principal Component (Variable point segments)

New HPC: New Hybrid Dependent & Independent Principal Component (Variable point segments and PCs are derived from on-line dependent and off-line independent historical/pre-computed data)

Note: 1. New DPC achieves better compression than old DPC
2. New HPC requires much less on-board processing than New DPC but degrades compression performance

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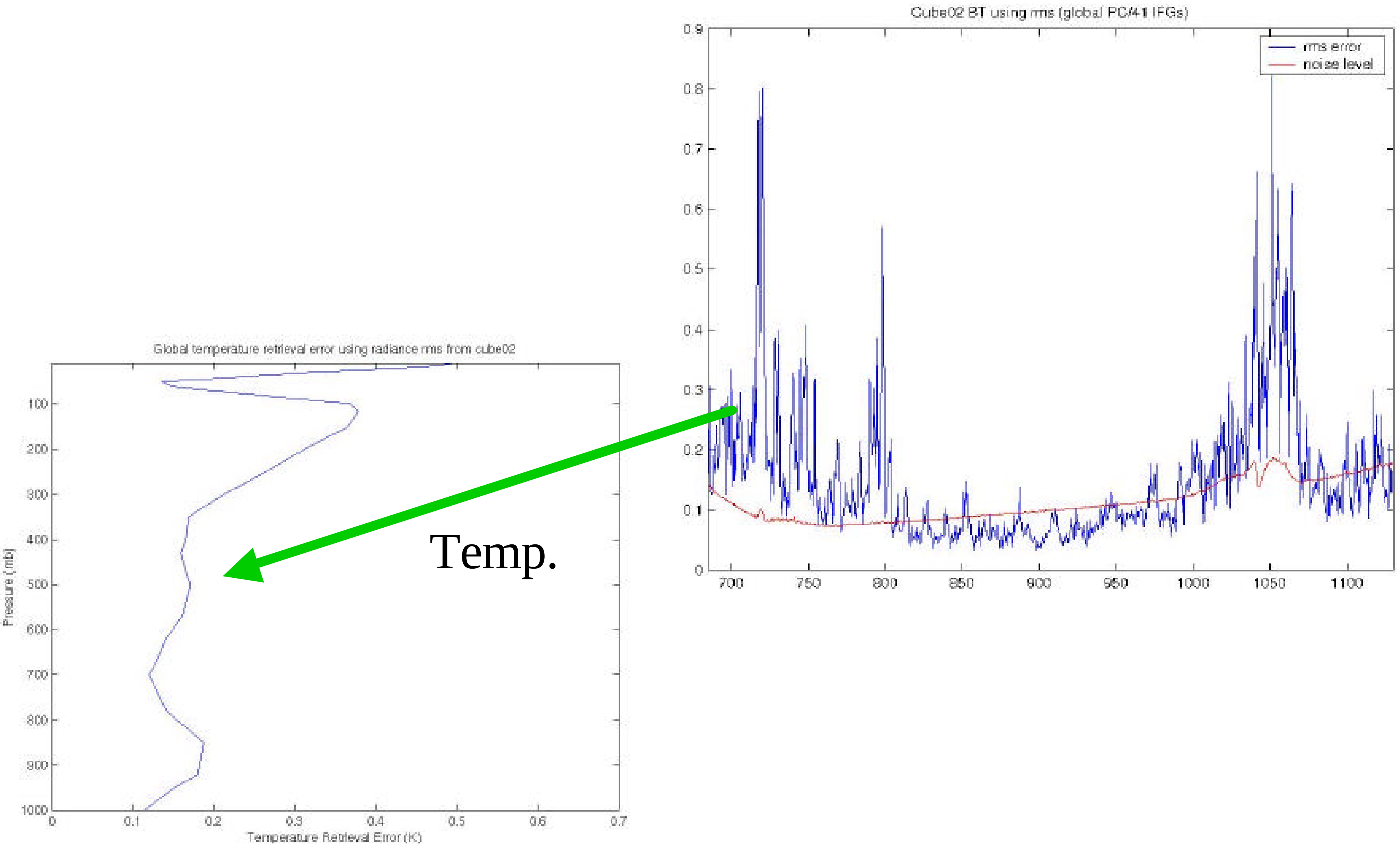
HPC Compression Impact on Retrieval - Cube 2



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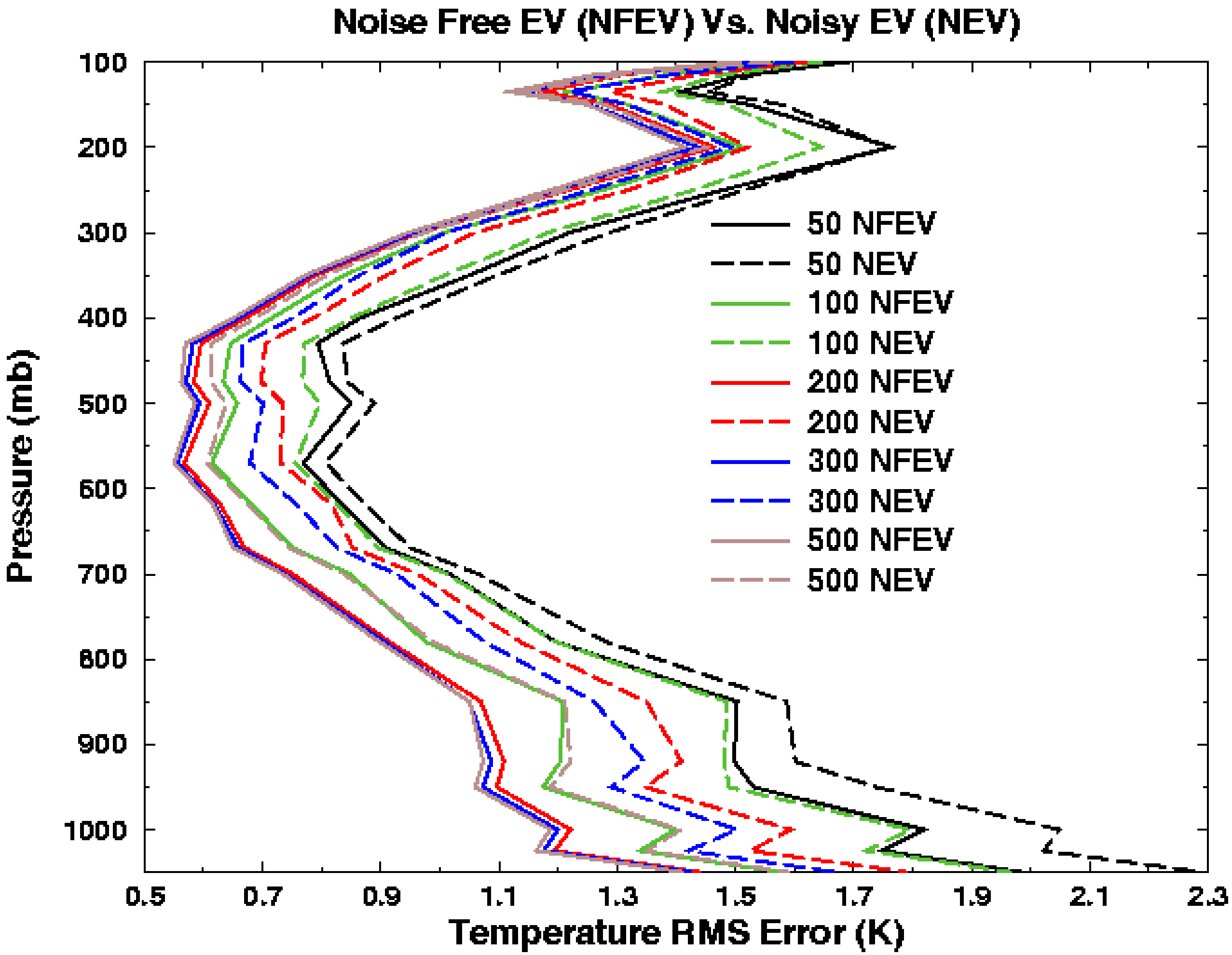
GIFTS Compression/Retrieval Analysis



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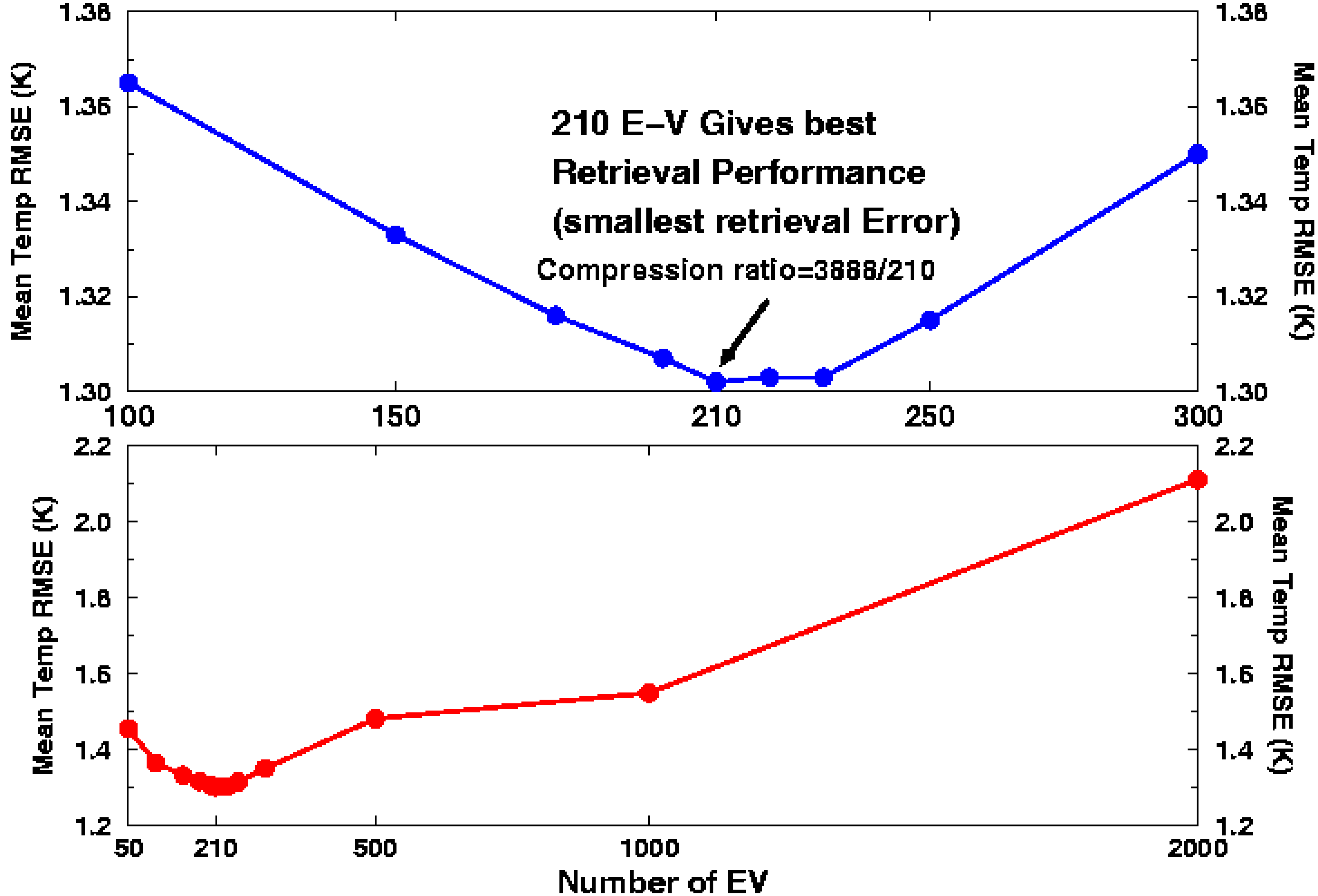
GIFTS Data Compression Retrieval Error

Only Optimal Compression Can Improve Retrieval Performance



HPC On-board Compression Processing Requirement

- Computational Requirements
  - PC Generation
    - Mean : 2008*(41+1)=84336 flops=0.08 Mflops
    - COV : for 150*41*2 & 448*41 matrix -> 1.88*2+16.7 Mflops = 20.5 Mflops
    - SVD : 9.4*2+244 Mflops -> 262.8 Mflops
  - PC Compression
    - [630*(20+1)+150*(20+1)*2+448*(20+1)]*16384 -> 474 Mflops
  - Total = 0.08+20.5+262.8+474 = 757 Mflops

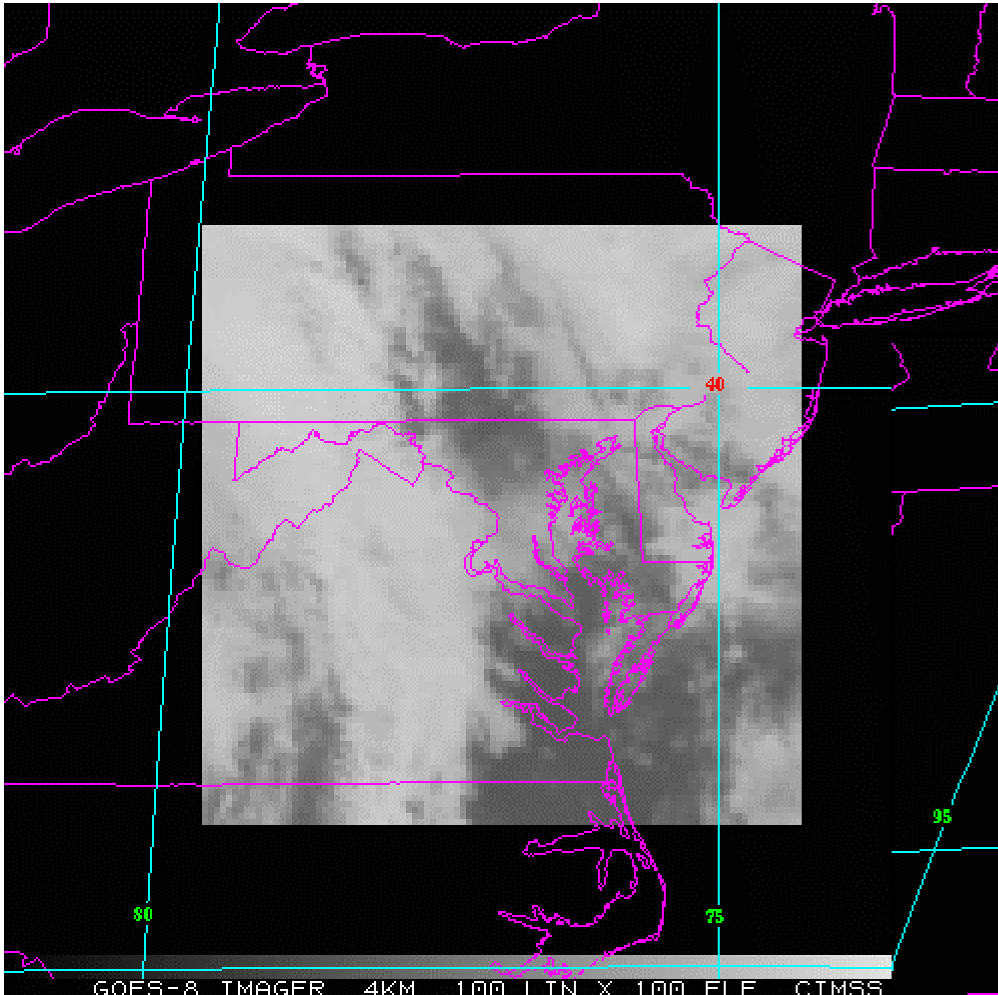
HPC On-Board Compression Processing Requirement

- Memory Requirements
  - PC Coefficients
    - Mean : 2008*16 = 0.03 Mbytes
    - COV : (630*630*16*2)+(150*150*16*2)+(448*448*16) = 16.62 Mbytes
    - PCs : 2*(20*630*16)+2*(20*150*16)+(20*448*16) = 0.64 Mbytes
  - Interferograms
    - Training : 41*2048*32 = 2.7 Mbytes
    - Cube data : 16384*2048*32 = 1073 Mbytes
  - Total = 1093 Mbytes

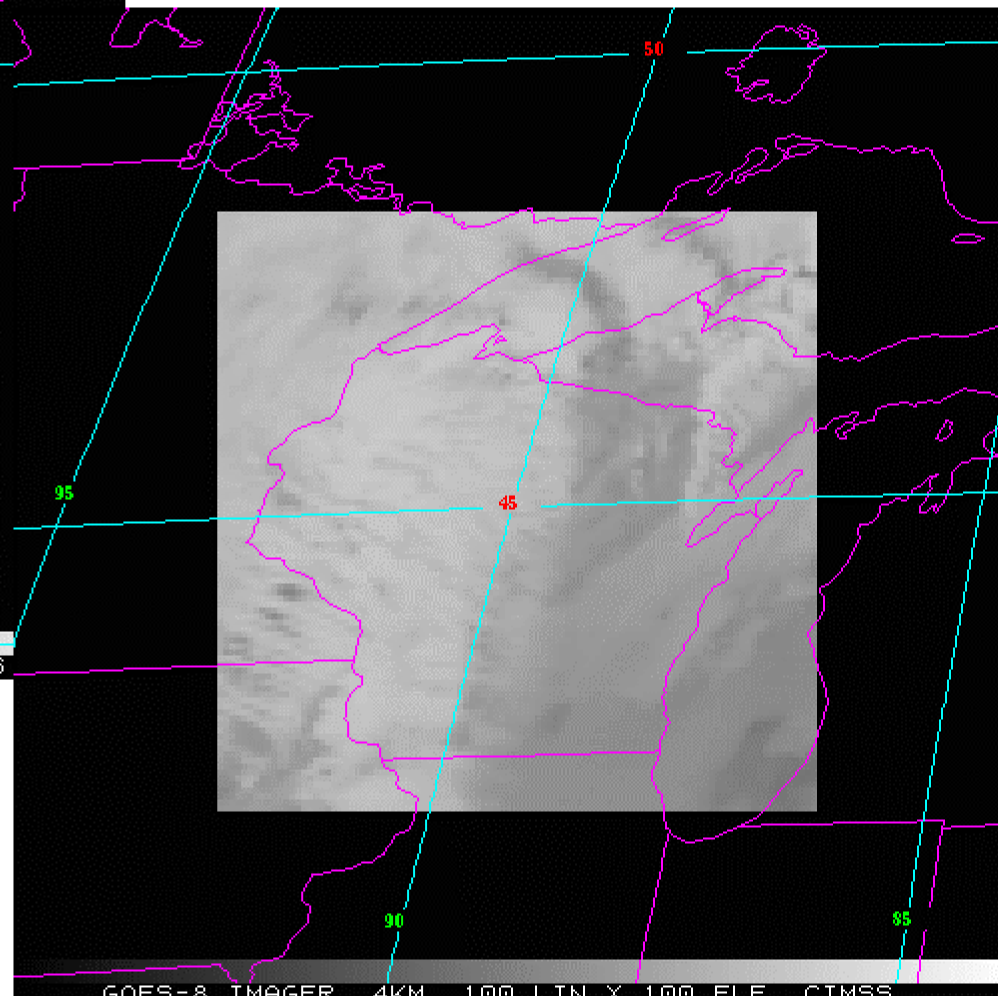
Onboard Computing Requirements

- Calibration
  - $4N + N\log_2(N)$ order calculation per interferogram
  - 15 ops per point LW; 16 ops per point S/MW
- Resampling from self-apodized state
  - $59N + 9N\log_2(N)$ order calculation per interferogram
  - 158 ops per point LW; 167 ops per point S/MW
  - can be mitigated by pre-interpolating raw interferograms before filtering
- Compression by Principal Component Analysis
  - $M*N$ order calculation per interferogram for M PCs
  - M=100 implies 100 ops per point

Potential DPC Processing Domain



DC



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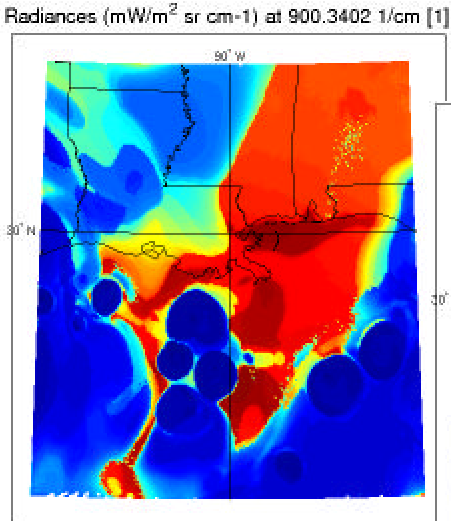
Potential ABS Dataset for Compression Study



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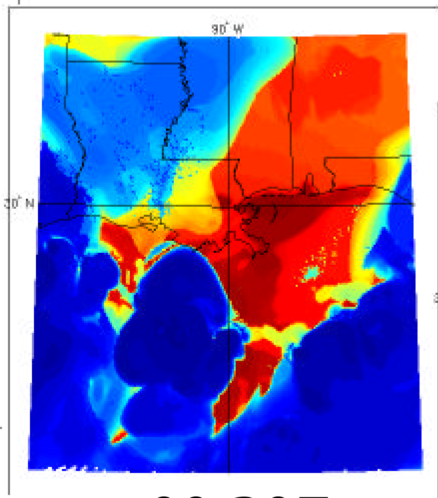

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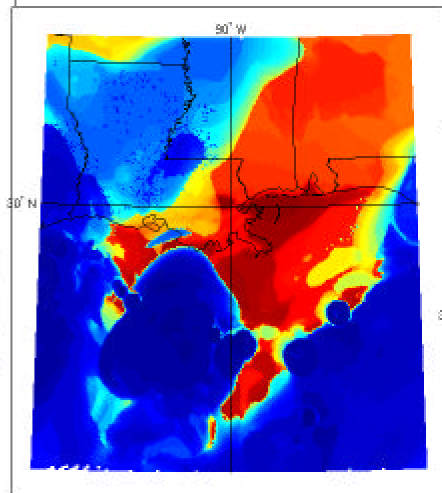

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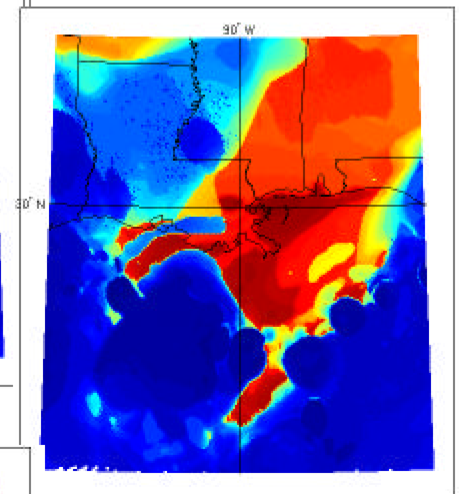

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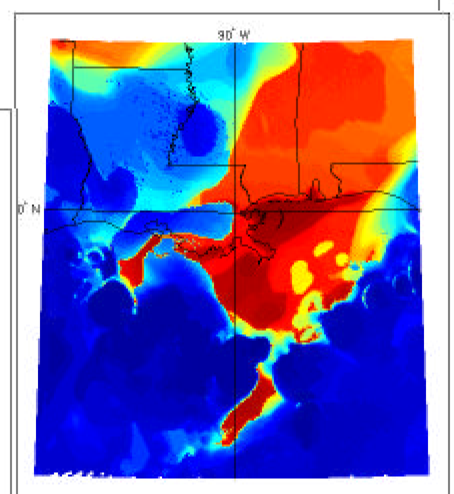

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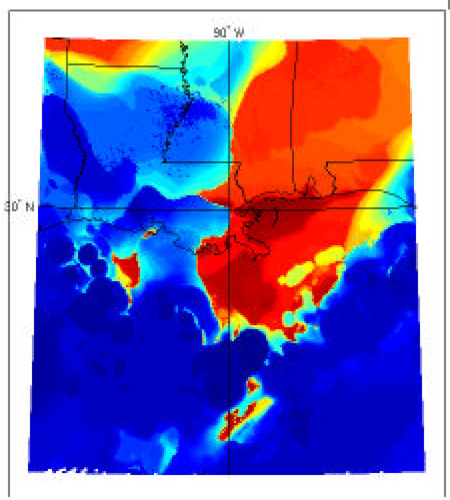

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Implementation Roadmap for ABS Hyperspectral Data Compressing

Measurement Simulation:
Atmospheric Condition Modeling
TOA Radiance Modeling
Instrument Effect Modeling
Calibration Modeling

Processing Implementation:
On-Board
Ground-Based
Validation

Data Compression Study:
Raw/Calibrated Spectral Domain
Raw/Calibrated Spatial Domain
Dependent/Independent Domain
PC/EOF/SVD Transformation Approach
Wavelets Transformation Approach
Quantization/Coding
On-board/Ground-Based

Noise Estimates

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Responsibility Roadmap for ABS Data Compressing

NOAA/Government:
Defined User Needs
Set Requirement
Coordinate Industry & Research Center

Industry:
Instrument Expertise
Space Qualified Parts
Design/Implementation

Research Centers:
Conduct Simulation
Conduct Processing Study
Define Processing Needs
Define Feasibility
Recommend Solution

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Roadmap for ABS Data Compressing Study

1. Leveraging of NASA GIFTS on-board compression work

1-1. Processing Algorithm - Continue to optimize DPCC approach

1-2. Processing Requirements - Refine requirement for ABS efficient ground-based and on-board compression

1-3. Measurement/Products Impacts - Reconfirm compression impacts on both level-1 and level-2 data

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Roadmap for ABS Data Compressing Study - continue

2. Adapting GIFTS Compression work with Enhancement/Improvement

2-1. Test enhancement of numerical method of deriving DPCC used in GIFTS experiment

2-2. Test variety of similar (non-PC) numerical techniques and inter-compare their respective performance and efficiency

3. Comparing Image and Spectral Compression Technique

3-1. Compare product impact of image (I.e. JPG 2000) and interferogram/spectral domain compression

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Roadmap for ABS Data Compressing Study - continue

4. Modeling ABS Instrument Measurements

4-1. Develop ABS specific radiative transfer model

4-2. Model ABS instrument outputs - both signal & noise

4-3. Simulate ABS geo-orbital high temporal and spatially coherent measurements using high spatial resolution numerical model output and/or data cubes from field experiments

4-4. Modeling ABS pre-processing and calibration procedure

4-5. Provide ABS raw interferogram and calibrated spectral images

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Roadmap for ABS Data Compressing Study - continue

5. Define Tradeoff Disadvantages/Benefits for "Lossless" and Lossy" Compression Approaches

6. Extended ABS compression study – use not only the data transformation based compression approach and to include all other compression components

6-1. Data quantization

6-2. Data coding and decoding

7. Define Performance for both Ground-based and On-board Compression

8. Make Recommendations for ABS Operational Consideration for Data Downlink and Ground Data Redistribution

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